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The Effect of Farm Manure in Liberating Plant Food from the Soil

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THE EFFECT OF FARM MANURE IN LIBERATING

PLANT FOOD FROM THE SOIL.

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Edward Riley Allen

ENTITLED THE EFFECT OF FARM MANURE IN LIBERATING PLANT FOOD FROM THE SOIL.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science

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INTRODUCTION.

It is a usually recognized fact in problems of soil fertility that farm manures have three distinct effects on the soil, namely,- (1) the direct addition of plant food; (2) the improvement of bacteriological conditions; and (3) the addition of humus or vegetable matter. This latter consideration involves several minor ones, such as increased capillarity, water holding capacity, porosity, and the liberation of plant food already present but in an unavailable form in the undecomposed mineral soil particles, which particles are in reality portions of rocks. What has been said in agricultural literature regarding the liberating effect of farm manures has been said largely from a theoretical point of view , but on good hypotheses nevertheless. Not a great deal has been done to establish this particular point

OBJECT AND PLAN OF THE INVESTIGATION.

It was the object of this investigation to ascertain the effect of farm manures on the liberation of plant food in the soil, in so far as this effect could be detected by determining the amounts of certain elements of plant food obtained by leaching or percolation. Accordingly forty pots of soil were treated with different amounts of manure and ferilizerin different combinations, and then leached for a period of sixty days with an amount of water approximately equivalent to one half the mean annual rainfall. The combinations and quantities of the treatments were as follows:--

Manure alone added.

No. of Pot	1	2	3	4	5	6	7	8
Soil		Grams	per	pot.				
Sand	0	0	100	100	200	200	300	300
Gray Silt Loam	0	0	100	100	200	200	300	300
Brown Silt Loam	0	0	100	100	200	200	300	300

Manure added with 20 gms rock phosphate per pot.

No. of Pot	1	2	3	4	5	6	7	8
Soil		Grams	per	pot				
Gray Silt Loam	0	0	100	100	200	200	300	300
Brown Silt Loam	0	0	100	100	200	200	300	300

The equivalents of the applications in pounds per acre are as follows:--

100 grams -- --8 Tons.

200 grams--- --16 Tons .

300 grams -----24 Tons.

20 grams---- 3200 Pounds.

The pots used were ordinary four gallon glazed crockery jars. The percolate escaped through a single hole about 1/2 an inch in diameter in the bottom of the jars, and was caught in a bowl below. Directly over this hole was placed a small bunch of glass wool, and thisin turn was overlain by a piece of wire gauze.

The sand used was ordinary white quartz sand of medium coarse-ness.

The Gray Silt Loam used was the gray soil of the level timber land of the Early Wisconsin Glaciation. This soil contains a high

percentage of silt, and is very light in color, indicating a low percentage of organic matter.

The Brown Silt Loam used was the dark brown soil of the slightly rolling prairie land of the Early Wisconsin Glaciation. It is similar in texture to the Gray Silt Loam used except that it contains more organic matter.

Partial analyses of the soils showed the following percentages of nitrogen and phosphorus:--

	% N	% P
Gray Silt Loam	.18	.045
Brown Silt Loam	.26	.07

The manure used was fresh cow manure having the following percentages of nitrogen and phosphorus:--

Nitrogen..... .75%

Phosphorus ... .20%

Dry Matter ..21.18%

The leaching or percolation was very unsatisfactory and certainly was not conducive to accurate and comparable results. Particular difficulty was experienced with the gray silt which admitted of very slow percolation. Furthermore the rate of leaching was not the same in the different pots of this soil. Some of them would finish percolating in a few hours, while others would require three or four days, and as there was every gradation between these two extremes the leaching of this particular soil was very unsatisfactory. The brown silt leached more rapidly and uniformly, the amount of water (6 liters) which was applied at each leaching usually passing through in a few hours. However, some pots of this soil per-

colated very slowly and required a day or more to drain. The sand, of course, leached very rapidly, requiring perhaps less than half an hour for the six liters to pass through. These variations in the rates of leachings are not conducive to results that are strictly comparable.

CHEMICAL METHODS AND PERCENTAGE OF ERROR.

It was necessary to concentrate the percolate to 500 c.c., and then use aliquot parts of this amount for the analyses. Only two elements, nitrogen and phosphorus were determined. The nitrogen was determined by the ordinary Kjeldahl method, that is, digesting the substance with concentrated sulphuric acid, neutralizing with alkali, distilling and determining the nitrogen in the form of ammonia by titration. The phosphorus was determined by the Pemberton method, that is, precipitating with ammonium molybdate, filtering, dissolving the precipitate in standard KOH, and titrating the excess with HNO_3. The KOH used was ofsuch a strength that 10 c.c. of it would dissolve an amount of the precipitate containing .25 of a milligram of phosphorus. Much difficulty was experienced in getting the duplicates to check in the phosphorus determinations, and they had to be done the third time before any results at all consistent were obtained. From the duplicate analyses given in Table I the character and magnitude of the variation can be seen by the comparison of each pair of analyses which should be exact duplicates.

Table I. Duplicate Analyses of the Phosphorus in the Leachings.

Computed to parts per million of dry soil.

Manure applied per acre		None		8 Tons		16 Tons		24 Tons	
Soil	Analyses	1	2	3	4	5	6	7	8
Sand	First Second	.117 .133	.150 .145	.011 .044	.011 .016	.234 .212	.033 .033	2.00 1.98	.837 .859
Gray Silt Loam	First Second	.302 .270	.143 .143	Lost Lost	.302 .344	.286 .344	.740 .700	.445 Lost	.509 .430
Brown Silt Loam	First Second	.786 .852	.860 .999	1.048 1.048	.557 .589	.557 .688	.704 .655	.868 .868	.739 .731
	3200 lbs. rock phosphate per acre additional.								
Gray Silt Loam	First Second	.461 .465	.278 .286	.254 .222	.278 .246	.159 .175	.111 .111	.238 .230	.143 .096
	First Second	.376 .393	Lost Lost	.270 .327	.409 .376	.491 .426	.123 .139	.360 .352	.508 .475

Table II. Duplicate Analyses of the Nitrogen in the Leachings.

Computed to parts per million of dry soil.

Manure applied per acre		None		8 Tons		16 Tons		24 Tons	
Soil	Analyses	1	2	3	4	5	6	7	8
Sand	First Second	.439 .439	1.099 1.207	.384 .329	.329 .439	1.970 2.080	.329 .329	3.953 4.172	.988 .878
Gray Silt Loam	First Second	Trace Trace	Trace Trace	Lost Lost	.705 .470	1.645 1.723	3.291 3.291	1.567 1.253	.626 .470
Brown Silt Loam	First Second	1.333 1.067	1.867 1.333	3.201 3.201	1.600 1.867	1.600 1.477	1.867 1.867	3.468 3.468	2.134 1.867

These analyses show that there is considerable error or variation in the determinations in some cases. The amount of the plant food in the percolate was so small that it could not be accurately detected by the method used.

The following tables show the average analyses of all the lea leachings.

Table III. Average Determinations of the Phosphorus in Leachings.

Parts per million of dry soil.

Manure per acre	None		8 Tons		16 Tons		24 Tons	
Soil	1	2	3	4	5	6	7	8
Sand	.848	.147	.027	.013	.223	.033	1.990	1.250
Gray Silt Loam	.286	.143	Lost	.323	.315	.720	.445	.469
Brown Silt Loam	.819	.929	1.048	.573	.622	.680	.868	.730
3200 lbs. rock phosphate per acre additional								
Gray Silt Loam	.463	.282	.238	.262	.167	.114	.234	.119
Brown Silt Loam	.385	Lost	.299	.393	.458	.131	.356	.491

Table IV. Average Determinations of the Nitrogen in Leachings.

Parts per million of dry soil.

Manure per acre	None		8 Tons		16 Tons		24 Tons	
Soil	1	2	3	4	5	6	7	8
Sand	.439	1.153	.356	.384	2.032	3.294	4.064	.933
Gray Silt Loam	Trace	Trace	Lost	.586	1.684	3.291	1.410	.548
Brown Silt Loam	1.200	1.600	3.201	1.734	1.534	1.867	3.468	2.000

So far as these analyses show neither the application of barnyard manure nor of rock phosphate has any effect on the amount of nitrogen of phosphorus in the leachings. In Table III it seems that

less phosphorus was obtained where manure was applied than where it was not. The nitrogen determinations are open to criticism because in the process of evaporating the leachings down to 500 cc. it is probable that nitrogen in the form of ammonia was driven off.

The following table shows the results computed to parts per million of the percolate. These figures, however, are only an estimate in a way as the exact amount of the percolate was not determined. Altogether 26 liters were applied per pot, and in making these calculations it was estimated that 25 liters percolated through.

Table V. Parts of Phosphorus per Million of the Percolate.

Manure per acre	None		8 Tons		16 Tons		24 Tons	
Soil	1	2	3	4	5	6	7	8
Sand	.092	.132	.035	.012	.200	.030	1.780	.760
Gray Silt Loam	.180	.090	Lost	.202	.198	.452	.280	.294
Brown Silt Loam	.500	.560	.640	.350	.380	.410	.531	.445
3200 lbs. rock phosphate per acre additional.								
Gray Silt Loam	.291	.177	.150	.165	.210	.070	.147	.075
Brown Silt Loam	.234	Lost	.182	.240	.280	.080	.200	.300

Table VI. Parts of Nitrogen per Million of the Percolate.

Manure per acre	None		8 Tons		16 Tons		24 Tons	
Soil	1	2	3	4	5	6	7	8
Sand	.397	1.030	.319	.344	1.820	.295	3.640	.836
Gray Silt Loam	Trace	Trace	Lost	.369	1.056	2.066	.885	.344
Brown Silt Loam	.732	.976	1.953	1.058	.736	1.136	2.116	1.220

By comparing these tables with Table VII it will be seen that

the leachings obtained in this experiment do not differ markedly in composition from ordinary drainage water.

Table VIII. Nitrogen and Phosphorus, Parts per Million of Drainage Water.

(Voelcker, Frankland, and Way.)

No.	Field	Nitrogen	Phosphorus
1	[1] Under 12 Wheat Fields	15.95	.41
2	[1] Under 3 Wheat Fields	18.28	.16
3	[1] Under 4 Hop Fields	44.20	.62
4	[2] Unmanured Plot	6.85	---
5	[2] 14 Tons Farm Manure per A.	112.55	---
6	[2] Unmanured Plot	.90	.24

The drain water for numbers 4 and 5 were collected Jan. 13, 1868. In number 5 the manure was applied to the plot in the autumn previous. The drain water used in number 6 was collected April 21, 1868.

These results show that applications of manure increase somewhat the amount of nitrogen in the percolate, but there are not sufficient analyses to show that it increases the amount of phosphorus.

On page 146 of Volume V of Rothamsted Memoirs, Lawes and Gilbert in commenting on the tables showing the salt content of drainage waters say:- " The chlorine and soda applied in manure are retained only to a small extent either by the wheat crop or by the soil; sul-

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[1] Jour. Royal Agricultural Society, Vol. XVII, p 133.

[2] Rothamsted Memoirs, Vol. V, p 89-91.

phuric acid is retained to a somewhat greater extent. Phosphorus and Potassium are very perfectly retained, the part unassimilated by the crop being held by the soil chiefly in the upper layers; this is particularly true of the Phosphorus."

On page 145, regarding the loss of nitrates, they say:--"Nitrates are largely produced in the soil by the action of a living ferment on the nitrogenous matter and ammonia. Nitrification takes place chiefly in the upper layer of soil and is greatly favored by the presence of water, and by summer temperature. In the summer drain waters contain little or no nitrates, after harvest the nitrates reappear and are found in the water through the winter."

Regarding nitrification these authors have previously stated on page 120 in the discussion of a table as follows:--"The rape cake and farmyard manure were both applied to the land in the autumn; in each case the drainage waters are richest in nitrates in the winter. Nitrification proceeds far more slowly with these organic manures than it does in the case of the ammonium salts, the amount of nitrates lost by drainage even in a wet winter is thus much less considerable." This last comment explains somewhat the reason that the amount of nitrogen in the leachings was not increased by the application of manures to the pots as shown by TableVI. The time during which the leaching of the pots was done (60 days) was too short to allow for nitrification of the organic matter added.

KING'S EXPERIMENTS.

Professor F.H.King while in the Bureau of Soils at Washington D.C. did some work on the effect of manure on the soluble salt content of the soil. In his Bulletin "E" which was published by him at Madison Wisconsin is given a report of his experiments. They consisted of studies on 8 different soil types, 4 poor, and 4 strong ones. The poor types were Norfolk Sandy Soil and Selma Silt Loam, Goldsboro N.C.;and Norfolk Sand and Sassafras Sandy Loam,Upper Marlboro Md. The stronger ones were Hagerstown Clay Loam, and Hagerstown Loam, Lancaster Penn.; and Janesville and Miami Loams, Janesville Wisconsin.

Experiments were conducted to determine the effect of farm manure on the water soluble salts of these different soil when applied at the rates of 25, 50, 100, and 200 tons per acre. The 20 pound soil samples used were composites taken with the soil tube from the surface foot of the unfertilized plots of the respective types. The soils were made up to their optimum moisture condition, weighed out in 4 pound lots and treated with the following amounts of manure which was fresh cow dung taken from the lot within two or three days after dropping, dried at 100° C and ground to a powder.

Table VIII. Amounts of Manure Added and its Equivalent in Tons per A.

	No.1	No.2	No.3	No.4	No.5
Grams per 4# soil	0	14.18	28.35	56.77	113.4
Tons per acre 6".	0	25.22	50.43	100.87	201.73

The soils were kept in a moistened condition in Mason 2 qt. fruit jars, the mouths of which were closed with a loose cotton

plugs to prevent evaporation and to allow aeration. Once a week the jars and contents were thoroughly shaken to secure a uniform exchange of air throughout the entire volume of the soil. The jars were weighed at the beginning and from time to time during the experiment, and the loss from evaporation restored by the addition of water. At the end of a period of 65 days samples were examined for water soluble salts recoverable with distilled water. To procure the solution for analyses 100 grams of soil were weighed out, and 500 cc. of distilled water measured in a graduated flask. The soil was then placed ina mortar, enough water added so that a thick paste was formed from stirring with the pestle, which process was for the purpose of breaking down the granulations. The remainder of the 500cc. of water was then added and the whole stirred vigorously for 3 minutes. The supernatant liquid was drawn off and filtered until perfectly clear. From this solution the determinations of the salts were made by means of the photometric method described in Bulletin 22 of the Bureau of Soils.

A colorimetric determination of the water soluble salts in the manure was also made, and from the data thus obtained were computed the amounts of soluble salts added to the soil in the manure. Then, as determinations were made of the soluble salts in the soil before the manure was added, and also 65 days after it had been applied sufficient data were furnished, when brought together to evolve the following tables.

Table IX. Average effect of 25.22 Tons of Manure per Acre on the 4 poorer soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	19.86	1.0	11.8
In manure	.29	23.5	27.46
Total	20.15	24.5	39.26
Recovered at end of 60 da.	2.87	3.0	19.52
Retained in soil	17.27	22.39	19.74

Table X. Average effect of 25.22 Tons of Manure per Acre on the 4 stronger soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	36.8	2.6	16.8
In Manure	.38	25.3	29.72
Total	37.18	27.9	46.52
Recovered at end of 60 da.	16.04	2.79	21.07
Retained in soil	21.14	25.11	25.45

Table XI. Average effect of 50.43 Tons of Manure per Acre on

the 4 poorer soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	19.86	1.0	11.8
In manure	.70	47.0	54.92
Total	20.56	48.0	66.72
Recovered at end of 60da.	.64	6.13	28.35
Retained in soil	19.92	41.87	38.37

Table XII. Average effect of 50.43 Tons of Manure per Acre on

the 4 stronger soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	36.8	2.6	16.8
In manure	.76	50.5	59.25
Total	37.56	53.1	76.25
Recovered at end of 60 da.	7.98	4.6	28.47
Retained in soil	29.58	48.5	47.78

Table XIII. Average effect of 100.87 Tons of Manure per Acre on the 4 poorer soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	19.86	1.0	11.80
In manure	1.41	94.07	109.86
Total	21.27	95.03	121.66
Recovered at end of 60 da	2.36	12.39	57.15
Retained in soil	18.91	82.64	64.51

Table XIV. Average effect of 100.87 Tons of Manure per Acre on the 4 stronger soils.

Parts per million of dry soil.

Plant food in soluble form	N	P	K
In untreated soil	36.8	2.6	16.8
In manure	1.52	100.9	118.92
Total	38.32	103.5	135.72
Recovered at end of 60 da.	11.95	8.9	37.05
Retained in soil	26.37	94.6	98.67

Table XV. Average effect of 201.73 Tons of Manure per Acre on the 4 poorer soils

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	19.86	1.0	11.8
In manure	2.83	188.0	214.72
Total	22.69	189.0	226.52
Reccvered at end of 60 da.	.96	35.6	121.25
Retained in soil	21.73	153.4	105.27

Table XVI. Average effect of 201.73 Tons of Manure per Acre on the 4 stronger soils.

Parts per million of dry soil.

Plant Food in Soluble Form	N	P	K
In untreated soil	36.8	2.6	16.8
In manure	3.06	201.9	238.35
Total	39.86	204.5	255.15
Recoverable at end of 60 da	.81	26.40	85.90
Retained in the soil	39.05	178.1	169.25

Table XVII. Summary of Amounts of Elements of Plant Food Retained in the Soil.

Parts per million of dry soil.

Manure applied	25.22 Tons	50.43 Tons	100.87 Tons	201.73 Tons
Soils	Potassium.			
4 stronger	25.45	47.78	98.67	169.25
4 poorer	19.74	38.37	64.51	105.27
	Nitrogen			
4 stronger	21.14	29.58	26.37	39.05
4 poorer	17.27	19.92	18.91	21.73
	Phosphorus			
4 stronger	25.11	48.50	94.60	178.10
4 poorer	22.39	41.87	82.64	153.4[illegible]

On page 41 of Prof. King's bulletin "E" is given a table the same as Table XVII above only the amounts (except of potassium) are expressed as the salt instead of as the elements. These results that King has computed do not in every case agree exactly with Table XVII. King's table computed to parts of the elements, instead of parts of the salts per million is as follows:---

Table XVIII. Elements Added in Soluble Form but not Recovered at the End of 65 Days.(King).

Manure applied	25.22 Tons	50.43 Tons	100.87 Tons	201.73 Tons
Soils		Potassium		
4 stronger	25.46	47.79	98.68	169.25
4 poorer	19.76	38.38	62.01	100.53
		Nitrogen		
4 stronger	21.13	21.47	30.64	39.02
4 poorer	18.62	18.97	18.96	21.78
		Potassium		
4 stronger	25.12	48.50	95.44	178.12
4 poorer	22.39	41.88	82.64	153.40

The figures in Table XVIII which are underscored are those that do not agree with the corresponding ones in Table XVII. This discrepancy, however, does not effect the results materially, the same principle being brought by either table. From these figures it seems that the amount of soluble plant food in the soil that has had manure incorporated with it for 65 days is less than the sum of the original soluble plant food of the soil plus that which was added in the manure. Manure, therefore, so far as these figures show has the opposite of a liberating effect on the plant food of the soil. However, at the same time that Prof. King made these determinations of nitrogen, phosphorus, and potassium, he also determined the amounts of other salts in the soil, among which were sulphates, bicarbonates, and chlorides. With these salts

there was in every case a greater amount recoverable with water at the end of 65 days than there was present in the soil plus that in the manure. According to these experiments, then, farm manure does have a liberating effect on the sulphates, bicarbonates, and chlorides for the salts, without exception, went into solution in increasing quantities as the amounts of manure were increased.

In addition to his experiments in which the salts were recovered by vigorous agitation of the soil for 3 minutes with distilled water, Prof. King did some work on the amounts of salts recovered from heavily manured soils by continous percolation. For this work only two soils were used, the Janesville Loam and the Norfolk Sand, representing the strong and poor types of soils respectively. 206 days after the manure had been first incorporated in the soil, samples were taken for percolation tests from those lots which had had the manure applied at the rate of 200 tons per acre. The weight of the air-dry samples used in the percolation experiments were as follows: - Janesville Loam 119.2 grams, and Norfolk Sand 154.3 grams. These amounts were packed in a moistened condition in a Pasteur filter, in which they formed a layer 3/16 of an inch thick, and then subjected to slow, continous, uniform, percolation with distilled water until 6000 cc. had been collected. By the comparison of the amounts of salts thus recovered with the original amounts in the soil and manure, the effect of the manure is shown.

Table XIX. Effect of Manure at the Rate of 200 Tons per Acre on the Soluble Salts when Incorporated in the Soil for 206 Days.

Parts per million of dry soil.

I. Janesville Loam.

Salts Present	N	P	K	SO_4	HCO_3	Cl.
In Soil	40.1	5.75	19.12	36.2	20.	2.
In Manure	3.12	205.65	242.16	25.22	57.98	204.9
Total	43.22	211.40	261.28	61.42	77.98	206.9
Recovered	43.87	14.31	104.62	222.33	372.22	50.30
Retained	-.65	197.09	156.66	-160.91	-294.24	156.60
II. Norfolk Sand.						
In Soil	16.15	.77	11.92	9.9	14.00	4.00
In Manure	2.79	182.46	216.05	22.5	51.73	182.81
Total	18.84	183.23	227.97	32.4	65.73	186.81
Recovered	33.24	11.9	62.24	118.26	412.34	39.90
Retained	-14.40	171.33	165.73	-85.86	-346.61	147.91

Table XIX is open to the criticism that the salts present in the untreated soil were determined by agitating the soil with water while those recovered at the end of 206 days were determined by percolation. However, the error from this source is probably not large and the tables may be taken as representing reasonably accurately the effect of the manure.

It will be seen that the amount of soluble nitrogen is increased by the application of manure, a fact which was not true at the end of 65 days. The amounts of the phosphorus and potassium recovered are not markedly different from those which were recovered at the

end of 65 days. The manure had a marked liberating effect on the sulphates and bicarbonates, but an absorbing effect on the chlorides.

CONCLUSIONS.

From the data brought together in this thesis, both regarding soluble salts or elements in a soluble form recoverable either by percolation or by stirring with water, it appears that in periods of 60 or 65 days farm manure has a retaining effect on the elements nitrogen, phosphorus, and potassium. In no case during this length of time has the amounts of these elements in the soluble form been equal to the amount added plus the amount already in the soil.

In periods of longer contact between the soil and the manure more nitrogen becomes available, so that its amounts may surpass the sum of those applied and those previously in the soil. However, longer contact between the soil and the manure does not seem to cause more phosphorus or more potassium to go into solution to any extent.

The liberating effect of the manure seems to be all exerted on the salts and elements of no plant food value. In Prof. King's experiments the sulphates, bicarbonates, and chlorides have in 65 day periods gone into solution in increasing quantities as the amounts of manure were increased.